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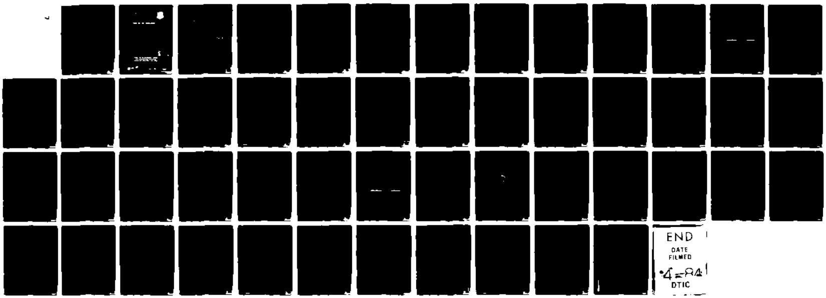

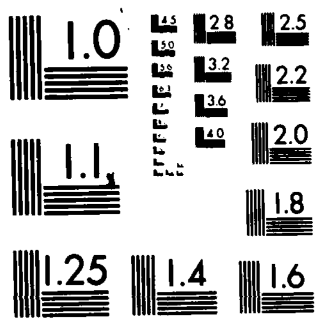

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RADC-TR-83-223
In-House Report
September 1983

C³I MODELING AND SIMULATION

Jack A. Mineo

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ROME AIR DEVELOPMENT CENTER
Air Force Systems Command
Griffiss Air Force Base, NY 13441

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This report describes an RADC approach for the application of modeling and simulation tools to analyze and enhance the C3I process. The report is based on detailed examination of both the C3I process and available modeling assets in light of the RADC mission and AF requirements. Included in this report is an assessment of the simulation and modeling State-Of-The-Art and the Air Force needs. The Technical Issues which must be addressed and the impact on RADC programs are discussed. The classic

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digital simulation approach is also detailed in Appendix A. This discussion on technical issues is followed by a plan to link available RADC models, laboratories and common databases, using a local area network fiber optics/CATV communications distribution system to form a broadbased C3I system analysis capability. The report makes several recommendations toward realizing this C3I analysis capability including an investment strategy, followed by a summary.

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I. INTRODUCTION

This report describes an RADC approach for the application of modeling and simulation tools to analyze and enhance the C3I process. The report is based on detailed examination of both the C3I process and available modeling assets in light of the RADC mission and AF requirements. Included in this report is an assessment of the simulation and modeling State-Of-The-Art and the Air Force needs. The Technical Issues which must be addressed and the impact on RADC programs are discussed. The classic digital simulation approach is also detailed in Appendix A. This discussion on technical issues is followed by a plan to link available RADC models, laboratories and common databases, using a local area network fiber optics/CATV communications distribution system to form a broadbased C3I system analysis capability. The report makes several recommendations toward realizing this C3I analysis capability including an investment strategy, followed by a summary.

II. MODELING & SIMULATION

STATE-OF-THE-ART

The state-of-the-art in modeling and simulation of C3I systems is maturing rapidly. Systems and equipments can be modeled, analyzed and designed with more depth and breadth than ever before. This process has been provided with the advent of; (1) increasingly more powerful computers, (2) more comprehensive high order system simulation languages, (3) expanded understanding of the measures of merit for system/sensors and their relationships, (4) use sophisticated user friendly man-machine interfaces, and (5) more powerful analysis and graphics display techniques. Models can now be constructed, and fine-tuned more rapidly and accurately with the aid of these tools and with less programmer-intensive effort.

Further, a review of ongoing simulation activities showed that numerous computerized models already now exist to help quantify and estimate performance aspects of C3I system and measure effectiveness in "specific" operational environments. These models range from large and extensive "War Gaming" models to highly detailed technology level models. However, it should be added that successful applications of these models for assessing the impact of new technology on C3I system/subsystem performance and/or missions effectiveness is not well defined. The models were

built independently of each other and therefore performance measures are highly dependent on how well the outputs from various models can be correlated. This correlation problem is based on taking a top down approach to simulation and modeling to drive technology by overall C3I system requirements rather than a technology or subsystem shopping list approach to system upgrades. Another area of concern is the present practice of evaluating system performance from a "specific" operational viewpoint i.e., ground war without air war leads to false simulation correlation problems.

This correlation process can now be aided with the improvement in modeling tools as pointed out earlier. Users are now able to easily generate and utilize scenarios, models, and model sets which allow simulation results to be created, analyzed and executed in a relatively timely manner. This tool responsiveness and ease of use, can and does play a very important role in the development of effective planning and decision aids. This development is made possible because of progress made on the development of; (1) sophisticated man-machine interfaces, (2) very powerful analysis, graphics techniques, (3) very high speed processors, (4) high speed volume data storage devices and (5) efficient data base management systems/machines. Further, advanced statistical, scientific and operations research subroutines are now available to aid in the performance evaluation of data analyses and data reduction tasks. This allows simulation results to be presented in summarized/understandable terms.

The state-of-the-art in interactive graphics display technology is also rapidly maturing. Terminal manufacturers are finalizing standards for hardware and software which will make the equipment more interchangeable and less costly. For example, color graphic systems continue to drop in price while increasing in capability. These new generation displays present a large amount of detailed information to the on-line user quickly in a clear and concise form.

Another factor playing an important role in simulation and modeling is the progress in the development of real-time data base management systems or data base machines. Knowledge base engineering continues to play a significant role in enhancing the utility of modeling/simulation tools via its ability to employ expert rule based judgment methodologies. Obviously, responsiveness and depth are tradeoff areas which will be considered in methodology selection for specific applications and objectives.

Finally, and possibly most important, the model validation process which is accomplished through the comparison of field testing with simulation results has made major strides. The results obtained from many large scale simulations have correlated very favorably with demonstrated performance results of actual hardware. The importance of this process is that once this model test validation occurs, the pay-off of a specific design may be judged in a system environment. It has been shown that data generated by some simulation models are so representative of those generated by actual hardware that test beds may now be built which consist of simulation models operating on-line with hardware devices, and sometimes interchangeably. In cases where software is modularly structured and written in like languages or cross-compilable languages, additional capability will be achieved since on-line host to host transportability of simulation models can be provided. Also I/O data structures which are compatible allow simulation models resident at different host computers to be "linked" or integrated together to work on a common simulation task.

At RADC, the linking of many available simulation assets and hardware test facilities will be achieved through the use of an RADC Local Area Network (LAN). This LAN will allow execution of simulations in various buildings and the transfer of results to other buildings. This capability will also facilitate the integration of simulation models from different divisions within RADC. This subject will be examined in detail in the approach section of this report.

III. ASSESS AIR FORCE NEEDS

The Air Force operational field commands communicate most of their needs through the use of Statements of Need (SON) and Required Operational Capability (ROC) documents. SONs and ROCs are invaluable inputs to the research and development process by identifying requirements in general operational terms. The result of this requirements definition approach is that specific programs are developed to address system issues independently and individually. The programs impact on the operational system as a whole is usually not considered or understood. Since C3I systems are large and complex, the Air Force has begun to recognize the subtle, yet dramatic, differences which exist between a "generic" conceptual C3I system and the actual deployed system. The Air Force is also beginning to realize that even highly qualified individuals and teams have difficulty describing their system due to both problems of perception and the sheer volume of data required. Therefore, the first

step which must be taken in developing C3I systems is to provide a common clearly understandable model of current system structures and future goals. This first step is a very important need of both the operational and technology community.

Once a common model of the C3I process is understood, simulation and modelling can be used as a common analysis vehicle for identifying C3I capability enhancements. Specifically it will improve/increase our capacity to understand and trace problem issues through a top-down "System Approach" to requirements delineation. Concepts can then be developed, evaluated and validated before modifications are implemented. Technology capabilities and limitations can be determined prior to purchase. Detailed designs must be evaluated and validated against total system configurations. Test plans are effectively developed to measure the important issues at hand and performance of the system under study. Finally, technology performance achieved can be measured against impact on specific theater C3I system environments and tailored to meet user individual requirements.

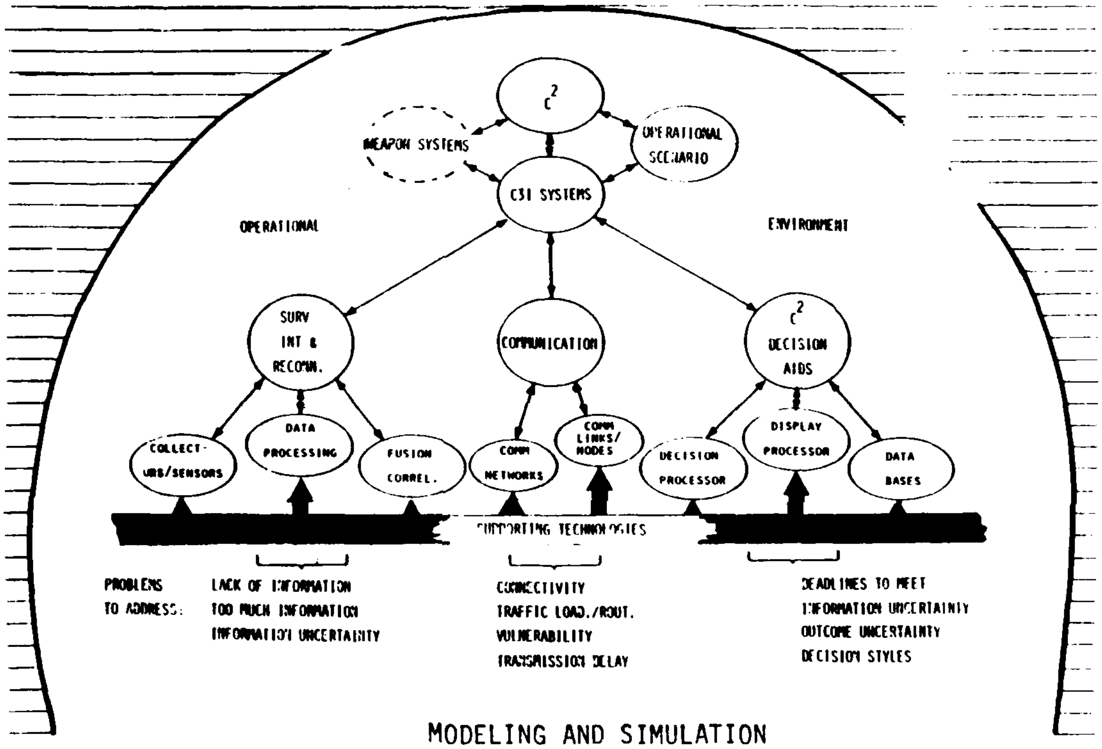
Further, with the computer's capacity to handle thousands of details, it is now possible to analyze the impact of new procedures on combined arms operations. Recent simulations have shown the methodologies for the integration of multiservices, allies and national agencies into a single set of representations. These models should also provide us with the ability to delineate and evaluate the interrelationships required for future multi-C3I system integration enhancements.

Models and simulations are also needed as C3I training aids to provide information tailored to the needs of the user and developer. Technologists can be taught to view the world from a stand point of total system ramifications. Acquisition officers can learn the functional requirement characteristics of C3I systems, in addition to the understanding of the unique attributes of specific technology. The operational user will then be provided a means to train new personnel, improve requirement operational procedure definition and be actively involved in the transfer technology and operational procedures.

IV. TECHNICAL ISSUES

Technical issues involved with C3I modeling and simulation are extremely complex because they are based on

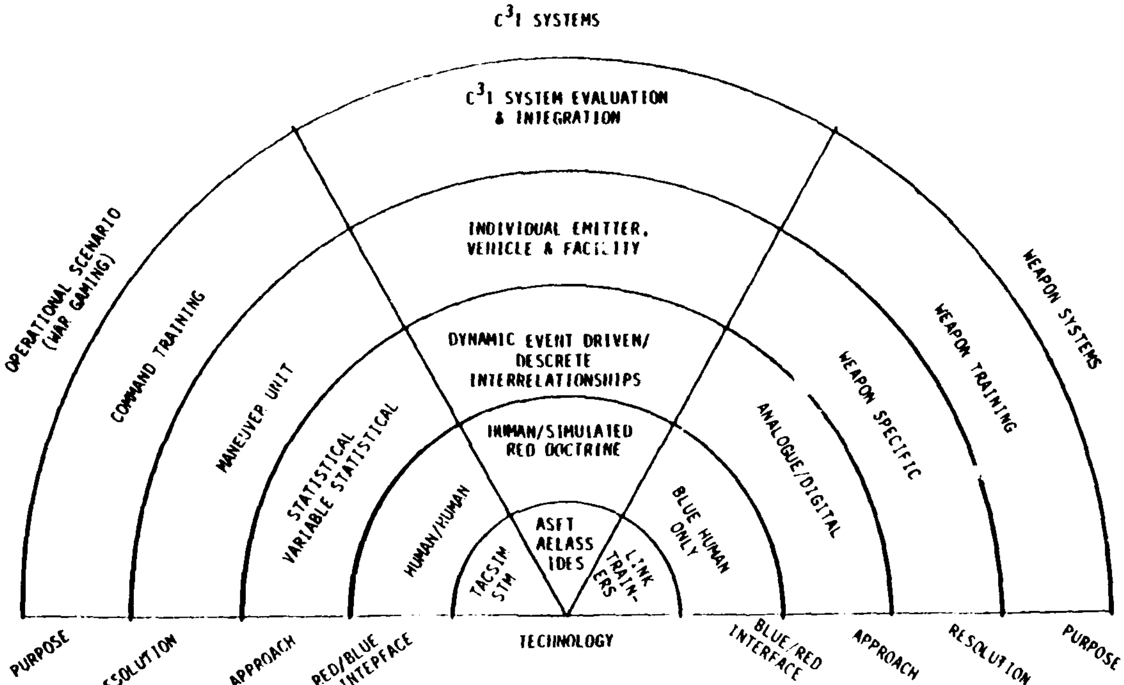
thorough understanding of C3I as well as the technologies which support the systems. The simulation and modeling process must reflect and detail user needs. Most importantly these processes must be validated using data bases from on-going real world test programs. The next few figures will outline the C3I model, the spectrum and the methodology being employed in this report.



MODELING AND SIMULATION
FIGURE 1

Figure 1 is a simplified depiction of the C3I orchestration process including weapon systems, operational scenarios and the various technologies. The objective of this orchestration is to provide the needed information to C2 battlefield managers and decision makers to control the available assets to meet dynamic changing threat environments. Obviously, the C3I orchestration process must vary with the missions being performed and detailed interactions will change to meet stated needs, but the system

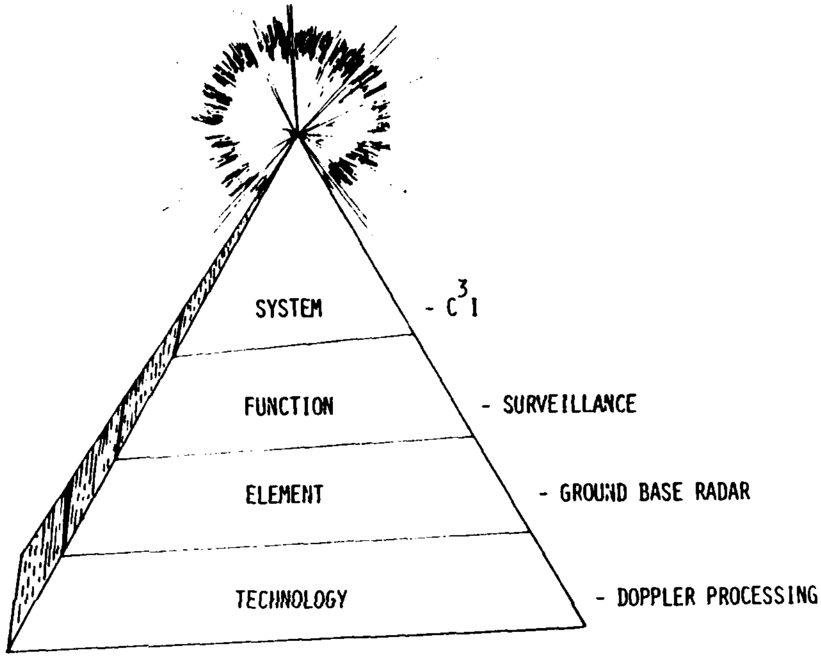
level focus of the C3I modeling must be maintained. Thus, a system approach to technology and requirements analysis will be used for problem solving. For example, the technology issues to be addressed in the communications area must be detailed with a thorough understanding of sensor data (type, volume, frequency, timeliness) from the Surveillance, Intelligence and Reconnaissance (SIR) area, data base requirements (format, volume, throughput) from the Decision Aids area and in light of operational/weapon system needs (Combat Information).



C2 SIMULATION SPECTRUM
FIGURE 2

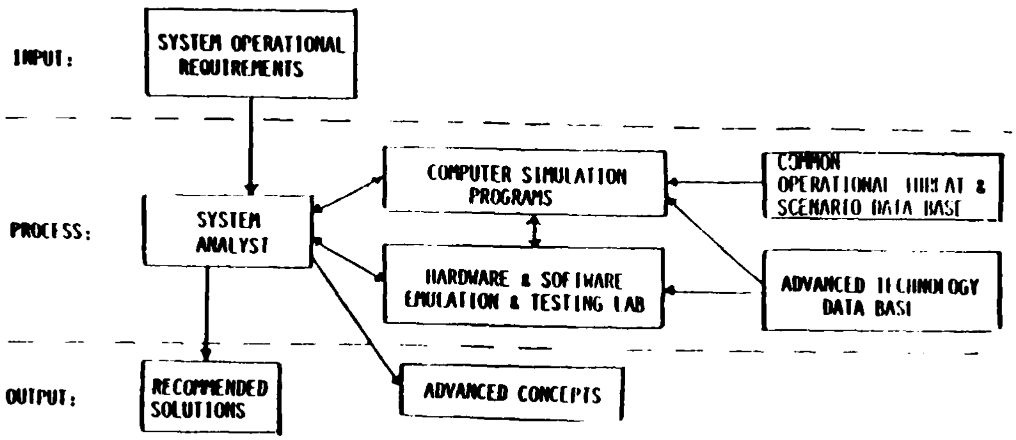
Further complicating the modeling and simulation process is the fact that simulation covers a number of types and application areas as shown in Figure 2. This spectrum includes war gaming, C3I system and Weapon Systems. Wargaming simulations are used as command and operational training vehicles and employ statistical data bases and processing routines with a great deal of human interface/ decision processes. Weapon system simulations are based on understanding details of an autonomous system and are also used for training purposes. The C3I system simulation falls directly between these two models in the process since it must maintain a command view point as well as understanding

of weapon system and the integration of the detailed characteristics of the system. Each of these simulations application areas provide excellent tools to be used in the modeling process. In fact, cross fertilization between the various model areas is critical to provide program performance evaluation.



MODELING AND SIMULATION
C3I TOP DOWN SIMULATION METHODOLOGY
FIGURE 3

Figures 3 and 4 depict the method and approach to C3I simulation modeling which provide the best payoff. The method as outlined in Figure 3 is a top down approach: i.e., system level models are supported in technological details by lower level function, element and technology models. System requirements are then properly factored into technology and vice/versa by this structure. The example shown on Figure 3 outlines a sample breakout of C3I, where the function of surveillance is supported through element levels of ground based radar and finally, the Technology level, doppler processing. Similar traces can be used for other mission areas.



MODELING AND SIMULATION
GENERIC SIMULATION & ANALYSIS FLOW DIAGRAM
FIGURE 4

The approach to modeling and simulation which must be advocated for useful results is shown in Figure 4. This approach is based on a top down simulation method, as previously outlined. The process is structured using integrated hardware/software assets controlled by a system analyst to simulate/emulate the problem, allowing understanding of detailed operational assets. This then provides the data base for recommendations for near term solutions and advanced concepts. Further, the simulation programs must interface with an operational threat data base which is common for all analysis processes. Our understanding of advanced technology must be factored into this structure. Most importantly, simulation, models and results must be validated with experimental and field testing. Thus the overall flow diagram shows a method to thoroughly examine a system, function, element or technology in detail, validate and extrapolate results to identify system pay-off and provide well founded validated recommendations.

V. ASSESS CURRENT RADC PROGRAMS

The C3I process can be segmented into four major Command, Control, Communications and Intelligence (C3I) mission areas. (1) Strategic C3I, (2) Tactical C3I (air), (3) Tactical C3I (ground), (4) Defense-Wide C3I.

The United States does not have a large investment in

strategic defensive weapons systems; and depends heavily on C3I to provide high confidence surveillance and warning. The Strategic C3I provides control and direction for the strategic triad. Strategic C3I is made up of three basic elements; (1) Strategic Surveillance and Warning, (2) Strategic Command Control Centers, and (3) Strategic Communications.

Tactical C3I (air and ground) supports the capability to fight in an autonomous and decentralized environment, to promote flexibility and decrease vulnerability. Centralized control and decentralized execution are vital ingredients to tactical air power and ground forces. The unique and diverse needs of various land, sea, and air force also can be broken down into three basic elements (1) Warning, Reconnaissance, Surveillance and Target Acquisition Systems, (2) Theater and Tactical Command Control Elements and (3) Tactical Communications.

Finally, the Defense wide C3I mission area is the application of a reliable C3I system in support of the Army, Navy and Air Force under the National Command Authority. The present thrust includes description and monitoring of enemy C3I activities while maintaining operable US C3I process providing the Commander with vital, timely information vice a flood of data. C3I modernization toward these objectives is vital to the Department of Defense (DOD).

The structure, interaction and payoff derived by a C3I approach to system development is a complex but worthwhile endeavor. C3I modeling and simulation can provide the flexible facility required to represent dynamic conflict situations with an accurate conflict data base with control and effective utilization of available assets. Within the current state-of-the-art, the understanding of C3I systems is based on individual disjoint knowledge and perceptions. An indepth understanding of the overall multifaceted interactions, data flow and authority/decision channels is needed and when assembled will permit detailed modeling of the C3I process. The Deputy Under Secretary of Defense (C3I) sponsored a workshop recently on Manned Simulator Testbeds for the Defensive Air Battle. The theme of this workshop was that the services must become an integrated force in coalition with our allies mandating interoperability. It was shown at the Symposium that people are the critical elements of the C3I process and success is possible only if they are properly trained. Finally, the development of "standards" in the area were emphasized.

In light of these C3I mission areas, the current RADC modeling and simulation programs were separated into three major categories; System Driven Models, Technology Driven Models and Hardware Simulators. The system driven models simulate C3I in various levels of detail but from operational threat perspectives, technology driven models are generally phenomenological, simulating very fine technological detail. Simulators, as presented here, are hardware devices which emulate the real world situation. Among the models/simulators at RADC, there are thirteen system driven models, thirteen technology driven models, and eleven simulators.

Figures 5, 6, and 7 are matrices of the models/simulation factored into their proper C3I mission area and evaluated against specific technology areas (i.e., Surveillance, Intelligence and Reconnaissance) (SIR), Communication, Command and Control (C2) and Decision Aids. The data base for this model classification was partially derived from authors knowledge of ongoing activities and survey reports of this area (See note 1)

	STRATEGIC C^3I	TACTICAL C^3I (AIR)	TACTICAL C^3I (GND)	DEFENSIVE-WIDE C^3I
AASR	• SIR	• SIR	• SIR	• SIR
ARM		• SIR		
ASE	• SIR		• SIR	• SIR
BRET	• SIR	• SIR		• SIR
C^3SAM		• C^2	• C^2	
DDG			• SIR	
DSS	• COM	• COM	• COM	• COM
FAP	• SIR/COM/C^2	• SIR/COM/C^2		
LOITER-ARW		• SIR		
TAC CONTROLLER		• SIR/COM		
TACOM II		• COM		
TASRAN	• SIR/COM	• SIR/COM		
TERSM	• SIR		• SIR	• SIR

CURRENT RADC PROGRAMS
FIGURE 5

	STRATEGIC C^3I	TACTICAL C^3I (AIR)	TACTICAL C^3I (GND)	DEFENSIVE-WIDE C^3I
ADAPT SAT ANT	•	•	•	•
AEISS	•	•	•	•
COMPUTER SIM OF DET TRK TGT	•	•		
DGTS	•	•	•	•
IDE				•
ICS	•	•	•	•
ICSSM	•	•	•	•
IEMCAP	•	•	•	•
INT SW SIM	•	•	•	•
IR&SS	•	•	•	•
PAAS	•	•	•	•
RADAR CLUTTER	•	•	•	
TRAFFIC SIM	•	•		•

TECHNOLOGY DRIVEN
FIGURE 6

MODEL	STRATEGIC C^3I	TACTICAL C^3I (AIR)	TACTICAL C^3I (GND)	DEFENSIVE-WIDE C^3I
DICEF	•	•	•	•
HF MEDIA	•	•	•	•
LOS ECM SIM	•	•	•	•
NANODATA QM1	•	•	•	•
OC SPL	•	•	•	•
QPRIM	•	•	•	•
SDDE	•	•	•	•
TROPOSCATTER	•	•	•	•
TROPO ECM	•	•		•
WIDEBAND LOS	•	•	•	•
WIRELINE SIM	•	•	•	•

SIMULATORS
FIGURE 7

Based on a review of the model classification data base, the committee members concluded that; (1) no one individual simulation met the requirements to accomplish the C3I analysis mission, (2) the C3I functions (i.e., Surveillance, Intelligence and Reconnaissance, Communications, Command and Control) are only partially factored into the system driven

Note 1 - "Survey of Simulation Models at RADC", Sep 82, Author: Mary Denz.

models and (3) uniform integration of the models and simulations is deficient. In order to accomplish a C3I simulation capability available models would have to be integrated. It was also noted that the operational data base varies widely between models. Also, to complete the evaluation, DOD simulations have been listed in Figure 8 and after review the above conclusions of the committee were also shown to be valid from these models.

- CATALOG OF WARGAMING AND MILITARY SIMULATION MODELS AVAILABLE (SAGA)
- ACCAT - ADVANCED COMMAND AND CONTROL ARCHITECTURE TESTBED (NOSC, SAN DIEGO)
- WES - WARFARE ENVIRONMENT SIMULATOR (AT ACCAT, NOSC, SAN DIEGO)
- TAWC - TACTICAL AIR WARFARE CENTER (EGLIN AFB)
- AEGIS - NAVY
- IDAGAM - IDA's GROUND AIR MODEL - CURRENTLY IN USE BY OJCS/SAGA
- JANUS - LAWRENCE LIVERMORE LABS
- QUICK - STRATEGIC WARGAMING MODEL - OJCS/SAGA
- TELMOD - FTD
- PAM - ADVANCED PENETRATION MODEL
- ESP - EVENT SEQUENCED PROGRAM
- ANTPAT - ANTENNA PATTERN - FTD
- NVLX - NAVY's NUCLEAR EXCHANGE MODEL
- SIGINT TACTICAL MODEL - NSA
- MEAP - MEASUREMENT, EFFECTIVENESS AND ASSESSMENT PROGRAM (NO LONGER OPERATIONAL)
- TAC ASSESSOR - USAF/SA
- TAC SUPPRESSOR - USAF/SA
- SMART - SIMULATION MONITORING, ANALYSIS REDUCTION AND TEST (LANGLEY AFB)

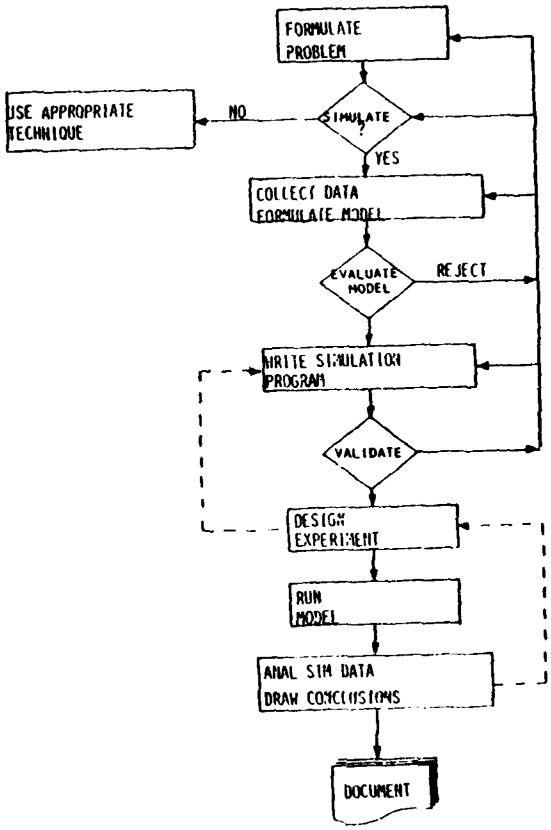
DOD PROGRAMS
FIGURE 8

Based on this analysis, RADC is planning several modeling and simulation programs using existing resources (i.e., ASE/TASRAN, SSF-ASE Interface, SIGINT-ASE Enhancement) to meet the needs of the C3I modeling process. This integration of existing RADC simulations for test and evaluation of new technology will be incorporated in the simulation structure of the C3I System Evaluation Facility. These simulations will plan a vital role in quantifying the effects of sensor and communications technology enhancements on C3I functions and performance. Details of the overall plan are outlined in the approach section of this report.

VI. APPROACH

The approach which will be used to meet the needs of C3I modeling will be an integration of available simulation and

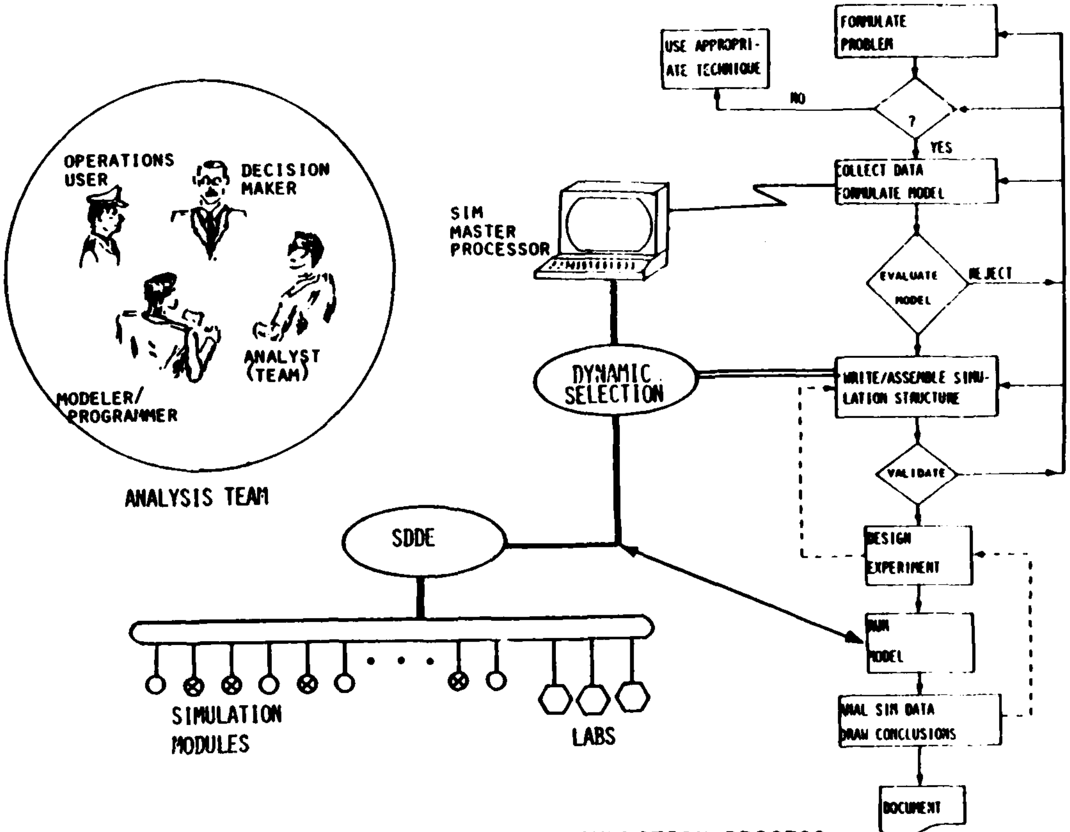
laboratories into a system evaluation facility. The key to this integration is the use of an available local area net at RADC to tie together the various assets. Classical system analysis and modeling approaches will be employed but from the standpoint of distributed modeling and data base situations. This section will present a classical approach to the application of digital simulation techniques toward system problem solving. We will then present this approach, enhanced by automated data processing.



CLASSICAL DEVELOPMENT DIGITAL
SIMULATION PROCESS
FIGURE 9

The Classical Approach, as can be seen in Figure 9 and detailed in Appendix A, is a straightforward, step-by-step process to simulation application. It, however, suggests

that each problem or issue under analysis requires the development of a unique set of software in order to obtain the desired results. At the time when models were vendor dependent, unstructured and ultimately discardable this approach was reasonable because it was the only one available. Today technology and simulation methodologies have progressed to a level which allows analysts to apply a modular (building block) approach to simulation application. The Classical Approach diagram most effectively addresses the requirements of single complex simulation technology problems. Requirements which are multi-faceted and need to be satisfied by analysis teams with balanced experience and simulation judgment need a different approach. This approach must be based on integration of facilities and analyst talents to solve complex C3I system problems.



MODULAR C3I SIMULATION PROCESS
FIGURE 10

This approach to provide a modular C3I simulation process for integration of RADC assets into a C3I capability is presented in Figure 10. This process uses the same steps as the classical approach but with some major changes. This enhancement is provided by the use of an automated simulation development process, RADC LAN and the integration of a team of analysts to develop and run simulation/analysis process.

The analysis team in Figure 10 is composed of experts in the fields of operations, research, system technology analysis and computer software; collectively directed and managed by the team leader with participation from user community. As a team, they bring to the simulation process the knowledge and experience needed to create a useful model. With each analysis application the specific composition of this team may vary in both size and composition, yet the importance of representatives from each of these fields cannot be overstated to bring credence to conclusions needed in the analysis process.

Simulation modules and labs, shown in Figure 10, represent hardware, software tools, models, databases and various simulations currently located independently throughout the RADC mission divisions. Local Area Network (LAN) of the System Development Experiment (SDDE) now becomes the critical element in the enhanced simulation process and the linking of each of the modules and labs. This then allows users (i.e., analysis teams) access to a wide range of data, manipulation and analysis capabilities.

The creation of analysis teams and the availability of a modular simulation linkage provides the foundation for C3 analysis. The primary issue to be resolved is how the team will use the online diverse models.

Following the classical simulation process, the most visible impact will occur during the model formulation, simulation generation, and the computer systems operation and execution areas. The item of key interest to each of these areas is the ability to structure prototype system simulations via interactive modular selection. This dynamic selection is controlled and directed through a simulation master processor which would allow the user to manage the translation, compatibility, modification and linkage requirements. The simulation master processor would also provide the means through which very high order simulation language capabilities can be utilized to generate new simulation programs. An interactive terminal display and control capability would allow these functions to be

accomplished rapidly. Model formulation, using this enhanced concept, facilitates accessibility of results for analysis and the ease and speed with which changes can be fed back to the system.

VII. RECOMMENDATIONS

Modeling and Simulation

The following recommendations are based on analysis capabilities and requirements to enhance units needed for the modeling and simulation process. The recommendation will provide C3I simulation capabilities for RADC to provide a framework to better meet future C3I development needs for the Air Force.

(1) In the area of planning and program development, the modeling and simulation should be made an integral part of the planning and program development process at RADC. More consideration should be given to the use of the modeling and simulation capabilities available at RADC to solve the complex C3I problems facing the Air Force and DOD. Only through advanced program planning that incorporates available models and simulations can we begin to approach workable solutions.

(2) A well defined top-down modular C3I analysis structure should be developed. The elements of the structure should include common validated threat models, a network design, common data bases and the associated technologies of all the divisions. This has already begun in joint efforts between IR, OC, and CO, however, the structure and understanding of this structure needs to be an important part of C3I development.

(3) An essential element of C3I modeling is the development of a common data base to experiment against. Currently unique threat, operational environment and technology data bases are being developed for every model/simulation. It is time to take advantage of established data bases with all the essential elements for various operational missions. More importantly, the common data base makes possible direct (and comparisons of) results between models and field testing.

(4) In order to develop accurate and useful models it is essential that we obtain closer user and product division involvement. This involvement will lead to better

modeling requirements and more useful simulation capabilities. These capabilities must yield answers which can be used by the product divisions, as well as be fully understood by the user.

(5) It is most important to begin to exercise available simulation models. There is a need to exercise these models and validate the simulations if we are to truly develop and understand the C3I process.

(6) RADC must continue to work towards developing trained analysts, (both individuals and teams) that can be responsive to the need of the center in the area of modeling and simulation. RADC must have the capability to effectively and efficiently employ simulation to resolve technical problems. An important part of this capability is the cultivation of technical expertise to take advantage of the experience of RADC's people. Further, the use of models and scenarios by RADC technologists and operational product staff serves to effect two-way transitions - new technology to operations and operational requirement to developments.

(7) RADC is defining and implementing a modular C3I simulation process for the effective use of modeling and simulation (See Figure 6). This process should provide an acceptable approach and structured framework for developing models and simulations for RADC. It would be centered around the use of the SDDE/LAN and include features such as common data bases, models and the framework to integrate them. Too often in the past, simulations have been developed to solve a very specific problem and then have been abandoned, sacrificing significant financial investment. By developing and using a formal approach to modular modeling and simulation, we can more effectively use and reuse our models. This process would provide a simulation environment, attractive to RADC's engineers and to outside organizations, which is both user friendly and modular.

(8) In order to evaluate the models and simulations being used, we must develop meaningful measures of effectiveness and merit. Right now we cannot answer the key question of "How much improvement is added to combat effectiveness by C3I developments?" To get there we need the criteria to evaluate the models we are using, and it must be done for all levels of simulation and across all the technology areas.

(9) A full spectrum of simulation capabilities should be developed, from the macro level of wargaming and

network communications to detailed simulations such as the Wideband LOS Simulator to even more detailed VHSIC foundry fabrication. Our ultimate goal will be to feed the results of the more detailed simulations into higher and higher levels until we are back to the macro level and can begin to assess the overall utility of our technology insertion.

(10) RADC should begin to direct the applicability of simulation to a wider range of problems. Once the C3I Analysis Facility is developed and operational, real and simulated information can be integrated in a single experimental environment to replicate an entire system of C3I. The capability to do experiments of this scale opens up a whole new horizon of applicability. Interoperability problems must address much broader issues. In the program planning phase we should be aware that modeling/simulation can be a very effective tool for a wide variety of problems. We should also consider simulation as an alternative to hardware development in program evolution whenever practical. Changes in user requirements and/or design are much more easily accommodated in a model than in hardware.

(11) The last recommendation is that the Modeling and Simulation committee be continued with the charter to work toward these goals, with the support of the mission divisions and the RADC Staff.

APPENDIX A

Classical Simulation Process

1. Formulate Problem - In this step, the system analyst must clearly define the objectives of his anticipated evaluation/analysis effort. These objectives must then be analyzed in order to define those system parameters for which information needs are to be developed by evaluation. This in turn leads to a conceptual design of the evaluation process in terms of input data, process and out data. The conceptual design will then enable a key decision to be made: To simulate or not to simulate?

2. Decision to Simulate or Not Simulate - This decision depends on a cost trade-off involving several alternative ways of implementing the conceptual design of the evaluation process. The solution may lie in a numeric or mathematic equation. The cost of simulation in some situations may exceed the cost of building the breadboard system, or as another, the cost in reliability of using a software model of man-machine interface may indicate that a real man-machine interface be used in the evaluation. In general, simulation is the court of last resort and should be used only when no other practical solution exists.

3. Collect Data and Formulate Model - The scope of the evaluation process is defined and simulation is indicated as an appropriate technique. Now the analyst must construct a model representing those elements of the real world system which are relevant to his evaluation/analysis objectives. Data must be collected to set up, test and evaluate the model.

4. Evaluate Model - Model development will nearly always be a cyclical process of initial development/evaluation/redesign/redevelopment. The system analyst must be concerned with determining the domain of validity of the model, the resolution and accuracy of the model, the internal consistency of its parts while comparing these characteristics of the model with his objectives. As a general rule, the analyst should develop a model with no wider domain of validity or greater resolution than is required by the objectives (unless there is some perceived future use which would justify doing so). The development of a model may also serve to modify preceding steps in the process e.g., may lead the analyst to further data collection, or to change his conclusions about the cost effectiveness of the modeling approach.

5. Write Simulation Program - The system analyst must develop as software the finally validated model(s) and simulation programs which provide the dynamics under which the models are exercised, e.g., timing of events, changes of variables, etc. Just as the models were evaluated, the simulation program also must be validated as a next step.

6. Validate Simulation - This again will be a cyclical process of initial development/evaluation/redesign/redevelopment. The system analyst must insure that the simulation program, which dynamically employs the accepted model(s), validly represents the real flow of events. He must be concerned with the domain of validity resolution, accuracy, internal consistency, and the control and accessibility of the simulation to data within the process to support his end objectives. Failure to achieve a validated simulation will impact any of the preceding steps and require return back to that step for necessary revision.

7. Design Experiment - In reality, some experiment design, although at a vary high level, is done as early as the problem formulation step. Experiment design is performed in more detail in the formulation and simulation development steps, since the simulation must be developed with their application and objectives in mind. In this step, the experiment is finalized in terms of documented test plans and procedures which completely define test objectives, resources required, staffing, test operations, data collection and reporting, etc.

8. Run Model - With the documented guidance of the previous step, the experiment is performed by running the model(s) through the simulation.

9. Analyze Simulation Data and Draw Conclusions - In accordance with the objectives, the data available from the experiment are analyzed. Most frequently, the analysis will entail a comparison of results from multiple runs of the simulation, each employing a controlled variation in the model(s) or simulation program. The conclusions drawn will be relative assessments of performance measured for these variations. The conclusions may also indicate that a redesigned experiment or new simulation is called for.

APPENDIX B

MODELING AND SIMULATION BRIEFING

BRIEFING GIVEN AT RADC

ON

22 OCT 82

by

JACK A. MINEO

LIST OF COMMITTEE MEMBERS

JACK A. MINEO/OCTM/CHAIRMAN

M. DENZ/COTE

J. DUSSAULT/COAM

G. ELLIS/OCTM

W. Hartnett/IRAE

R. HINMAN/DCCD

P. LEONG/DCLF

MAJ L. PLESS/COAM

CAPT J. REED/OCDE

LT C. SHOOK/OCTM

J. WEBER/IRDA

MODELING AND SIMULATION

OUTLINE

- STATE OF THE ART
- ASSESS AIR FORCE NEEDS
- TECHNICAL ISSUES
- ASSESS CURRENT RADC PROGRAMS
- ASSESS DoD PROGRAMS
- APPROACH
- RECOMMENDATION
- INVESTMENT STRATEGY

STATE OF THE ART

MODELING & SIMULATION

- SIMULATIONS ARE AVAILABLE TO ESTIMATE PERFORMANCE REQUIREMENTS IN SPECIFIED OPERATIONAL ENVIRONMENTS.
- RESULTS OF SIMULATION BEING VALIDATED.
- MODELING TO TECHNOLOGY LEVEL AVAILABLE TO SYSTEMS ANALYST.
- INTERACTIVE MODEL/SCENARIO GENERATION AND IMPLEMENTATION CAPABILITY.
- REPROGRAMMABLE HARDWARE EVALUATION IN VARIOUS REAL WORLD CONDITIONS.
- INTEGRATION AND SUBSTITUTION OF HARDWARE FOR FURTHER EVALUATION BY SIMULATIONS.

STATE OF THE ART (cont'd)

MODELING AND SIMULATION

- METHODS FOR INTEGRATION OF SIMULATIONS HAVE BEEN DEMONSTRATED.
- SYSTEM MODELING DATA AVAILABLE FOR DECISION AIDS.
- LOCAL AREA NETWORKS AVAILABLE FOR SIMULATION/MODEL INTEGRATION (SDDE).
- SPECIAL PURPOSE SIMULATION LANGUAGES AVAILABLE.
- HIGH SPEED AND HIGH VOLUME DATA STORAGE DEVICES AVAILABLE.
- HOST TO HOST SIMULATION TRANSPORTABILITY AVAILABLE.
- INTERACTIVE GRAPHICS DISPLAY TECHNOLOGY IS MATURING.
- STATISTICAL/OPERATIONAL ANALYSES CAPABILITIES ARE AVAILABLE FOR APPLICATIONS.

ASSESS AIR FORCE NEEDS

MODELING AND SIMULATION

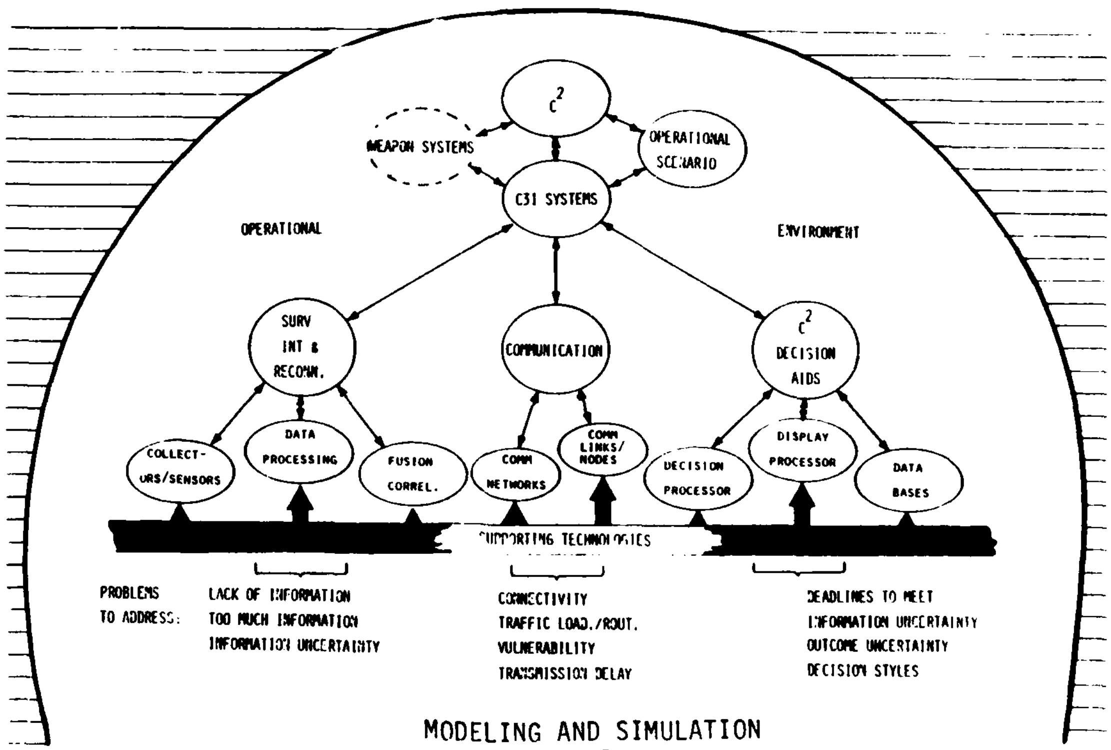
- PROVIDE A WELL DEFINED METHOD FOR SYSTEM/SUBSYSTEM/TECHNOLOGY DELINEATION IN C3I OPERATIONAL ENVIRONMENT
- PROVIDE A COMMON ANALYSIS VEHICLE FOR C3I CAPABILITY ENHANCEMENTS
  - PROBLEM AND REQUIREMENTS DELINEATION
  - CONCEPT EVALUATION/VALIDATION
  - TECHNOLOGY CAPABILITY/LIMITATIONS
  - DETAILED DESIGN EVALUATION/VALIDATION
  - TEST PLAN DERIVATION
  - TEST PERFORMANCE IMPACT ON C3I SYSTEM

<u>ASSESS AIR FORCE NEEDS</u> (CONT'D)

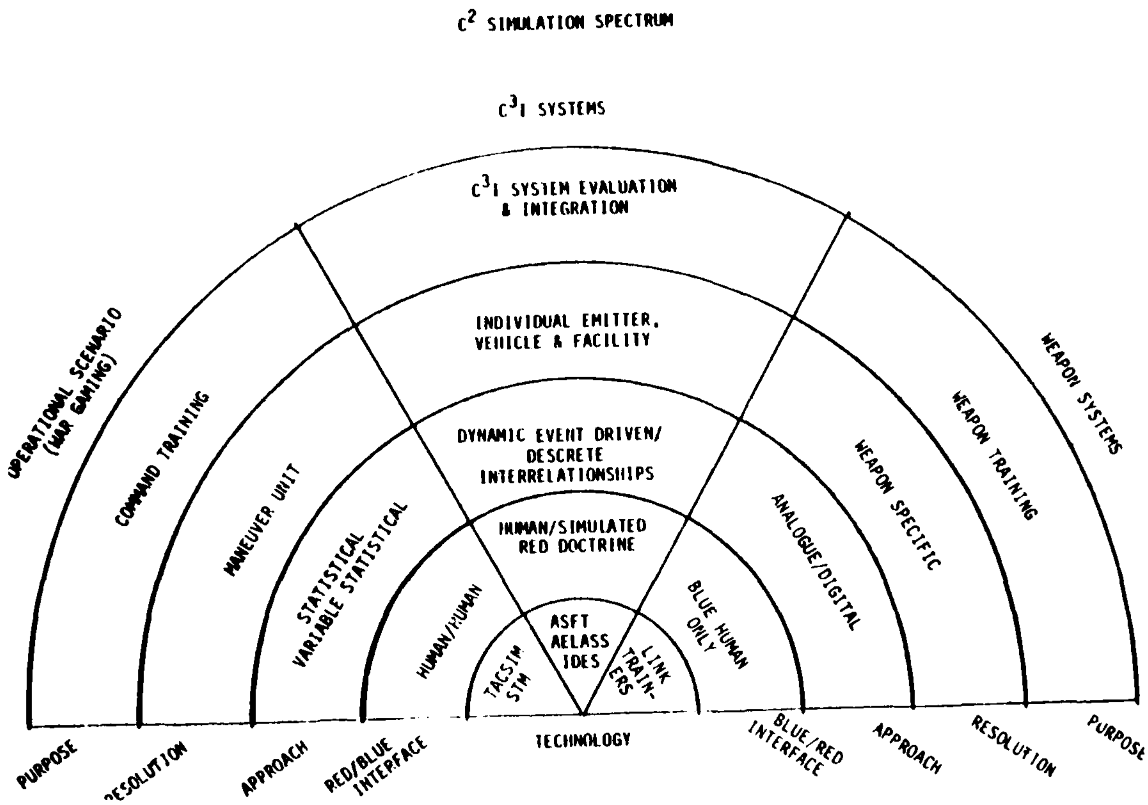
MODELING AND SIMULATION

- CAPABILITY DELINEATION, EVALUATION AND INTEGRATION OF COMBINED OPERATION
  - MULTI-SERVICE
  - ALLIES
  - NATIONAL AGENCIES
- C3I TRAINING AIDS
  - TECHNOLOGIES - SYSTEM RAMIFICATION
  - PRODUCT DIVISION - TECHNOLOGY TO SYSTEM RAMIFICATION
  - OPERATIONAL USER - REQUIREMENTS DEFINITION/TECHNOLOGY TRANSFER

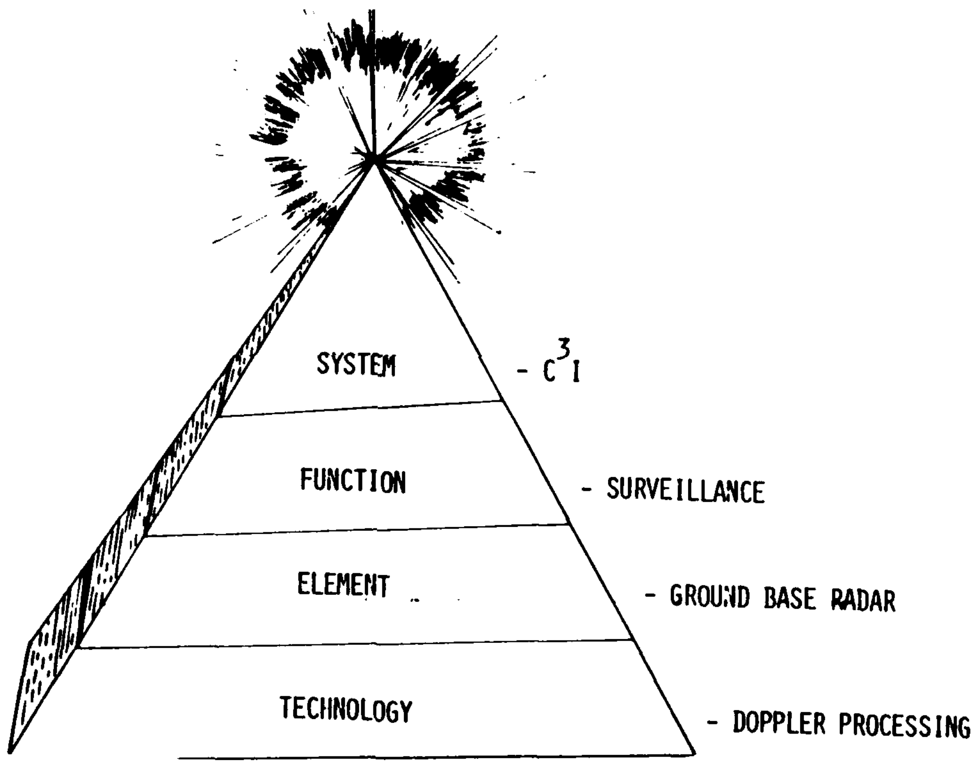
TECHNICAL ISSUES



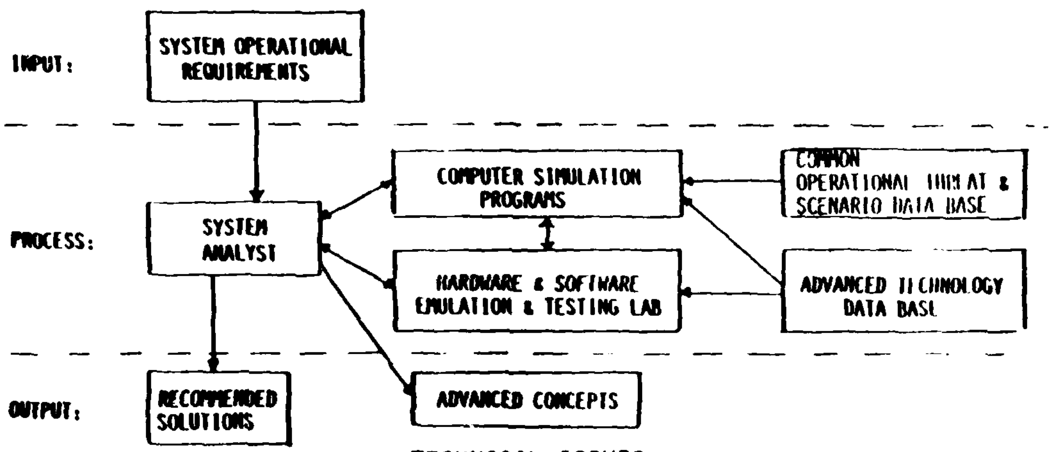
MODELING AND SIMULATION
FIGURE 1



C2 SIMULATION SPECTRUM
FIGURE 2



MODELING AND SIMULATION
C3I TOP DOWN SIMULATION METHODOLOGY
FIGURE 3



TECHNICAL ISSUES
MODELING AND SIMULATION
GENERIC SIMULATION & ANALYSIS FLOW DIAGRAM
FIGURE 4

	STRATEGIC C^3I	TACTICAL C^3I (AIR)	TACTICAL C^3I (GND)	DEFENSIVE-WIDE C^2I
AASR	• SIR	• SIR	• SIR	• SIR
ARM		• SIR		
ASE	• SIR		• SIR	• SIR
BRET	• SIR	• SIR		• SIR
C^3SAM		• C^2	• C^2	
DDG			• SIR	
DSS	• COM	• COM	• COM	• COM
FAP	• SIR/COM/C^2	• SIR/COM/C^2		
LOITER-ARW		• SIR		
TAC CONTROLLER		• SIR/COM		
TACOM II		• COM		
TASRAN	• SIR/COM	• SIR/COM		
TERSM	• SIR		• SIR	• SIR

CURRENT RADC PROGRAMS
FIGURE 5

	STRATEGIC C^3I	TACTICAL C^3I (AIR)	TACTICAL C^3I (GND)	DEFENSIVE-WIDE C^3I
ADAPT SAT ANT	•	•	•	•
AEISS	•	•	•	•
COMPUTER SIM OF DET TRK TGT	•	•		
DGTS	•	•	•	•
IDE				•
ICS	•	•	•	•
ICSSM	•	•	•	•
IEMCAP	•	•	•	•
INT SW SIM	•	•	•	•
IRSS	•	•	•	•
PAAS	•	•	•	•
RADAR CLUTTER	•	•	•	
TRAFFIC SIM	•	•		•

TECHNOLOGY DRIVEN
FIGURE 6

CURRENT RADC PROGRAMS

MODELING AND SIMULATION

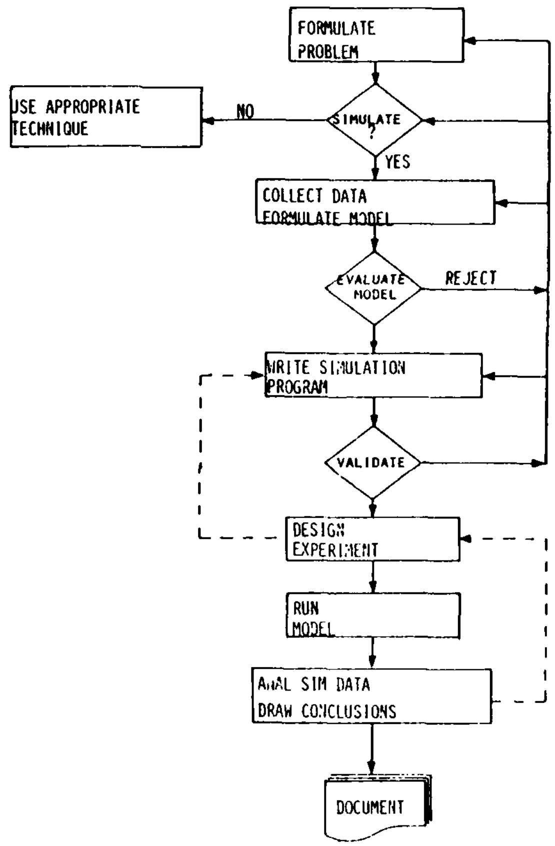
SIMULATORS

MODEL	STRATEGIC C^3I	TACTICAL C^3I (AIR)	TACTICAL C^3I (GND)	DEFENSIVE-WIDE C^3I
DICEF	•	•	•	•
HF MEDIA	•	•	•	•
LOS ECM SIM	•	•	•	•
NANODATA QM1	•	•	•	•
OC SPL	•	•	•	•
QPRIM	•	•	•	•
SDDE	•	•	•	•
TROPOSCATTER	•	•	•	•
TROPO ECM	•	•		•
WIDEBAND LOS	•	•	•	•
WIRELINE SIM	•	•	•	•

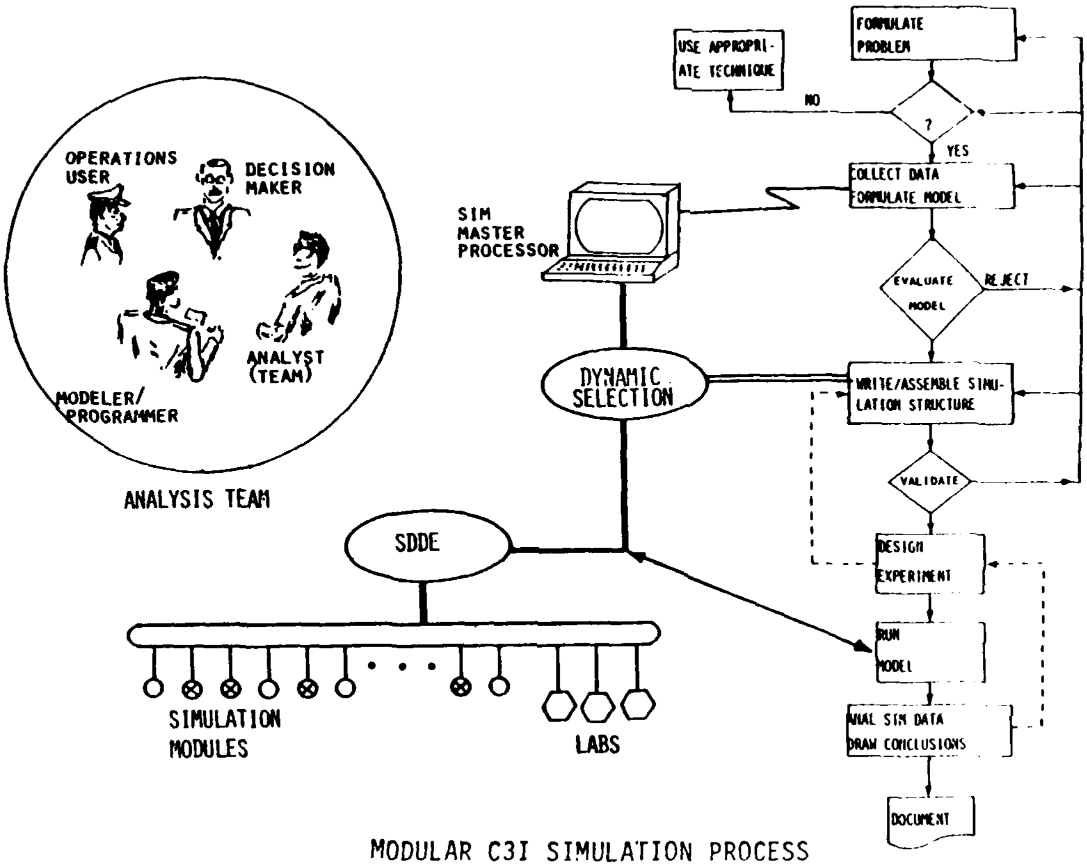
CURRENT RADC PROGRAMS
MODELING AND SIMULATION
SIMULATORS
FIGURE 7

DOD PROGRAMS

- CATALOG OF WARGAMING AND MILITARY SIMULATION MODELS AVAILABLE (SAGA)
- ACCAT - ADVANCED COMMAND AND CONTROL ARCHITECTURE TESTBED (NOSC, SAN DIEGO)
- WES - WARFARE ENVIRONMENT SIMULATOR (AT ACCAT, NOSC, SAN DIEGO)
- TAWC - TACTICAL AIR WARFARE CENTER (EGLIN AFB)
- AEGIS - NAVY
- IDAGAM - IDA'S GROUND AIR MODEL - OJCS/SAGA
- JANUS - Lawrence Livermore Labs
- QUICK - STRATEGIC WARGAMING MODEL - OJCS/SAGA
- TELMOD - FTD
- PAM - ADVANCED PENETRATION MODEL
- ESP - EVENT SEQUENCED PROGRAM
- ANTPAT - ANTENNA PATTERN - FTD
- NVEX - NAVY'S NUCLEAR EXCHANGE MODEL
- SIGINT TACTICAL MODEL - NSA
- MEAP - MEASUREMENT, EFFECTIVENESS AND ASSESSMENT PROGRAM (NO LONGER OPERATIONAL)
- TAC ASSESSOR - USAF/SA
- TAC SUPPRESSOR - USAF/SA
- SMART - SIMULATION MONITORING, ANALYSIS REDUCTION AND TEST (LANGLEY AFB)



CLASSICAL DEVELOPMENT DIGITAL
SIMULATION PROCESS
FIGURE 9



MODULAR C3I SIMULATION PROCESS
FIGURE 10

ASSESSMENT

ASSESS CURRENT RADC PROGRAMS

MODELING & SIMULATION

- INDIVIDUAL SIMULATIONS FUNCTIONAL, ELEMENT AND TECHNOLOGY MODELING AREAS ARE STRONG.

- C3I FUNCTIONS ARE ONLY PARTIALLY FACTORED INTO SYSTEM LEVEL MODELS

- INTERDIVISION USE AND UNIFORM INTEGRATION OF MODELS AND SIMULATION ARE DEFICIENT

- OPERATIONAL DATA BASE VARIES WIDELY BETWEEN MODELS

CURRENT PLANNED RADC PROGRAMS

MODELING AND SIMULATION

- ASE/TASRAN
- TACOM/TASRAN
- SSF-ASE INTERFACE
- SIGINT-ASE ENHANCEMENT
- ASE/C3M TARGET RECOGNITION DEMO
- BATTLEFIELD ACTIVITY SIMULATOR
- DGT/BLUE SCENARIO GENERATOR

CURRENT PLANNED RADC PROGRAMS (CONT'D)

MODELING AND SIMULATION

- o MULTI-NODE SENSOR CORRELATION INTERFACE ANALYSIS
- o AUTOMATED MULTISENSOR UNIT ID
- o NEAR-REAL-TIME COMBAT INFORMATION PROCESSING
- o FASP (HARDWARE)
- o ESAAP
- o ICS ENHANCEMENT
- o SIGINT NETWORK ENHANCEMENT
- o EISN

CURRENT PLANNED RADC PROGRAMS (CONT'D)

MODELING AND SIMULATION

- o TASRAN/E-3A
- o TASRAN/BMEWS
- o IRSS/PAAS
- o C2 SIMULATION LABORATORY
- o INTELLIGENCE SYSTEMS LABORATORY
- o ADVANCED SIGINT SYSTEM INFORMATION ANALYSIS
- o SIGINT IDENT TOOLS
- o ADVANCED SENSOR APPLICATIONS (IDHS)

RECOMMENDATIONS

MODELING AND SIMULATION

- MAKE SIMULATION AN INTEGRAL PART OF PLANNING AND PROGRAM DEVELOPMENT
- DEVELOP INTERDIVISION COORDINATION
  - ASE/TASRAN
  - TACOM/TASRAN
- DEVELOP COMMON DATA BASE
- NEED CLOSER USER AND PRODUCT DIVISION INVOLVEMENTS
- EXERCISE AND VALIDATE SIMULATION FACILITIES
- DEVELOP TRAINED ANALYSTS
  - INDIVIDUALS
  - TEAMS

RECOMMENDATIONS (CONT'D)

MODELING AND SIMULATION

- DEFINE AND IMPLEMENT MODULAR C3I SIMULATION PROCESS
  - SDDE
  - COMMON DATA BASIS AND MODELS
  - USER FRIENDLY EXPLOITATION
    - LANGUAGE TRANSPARENCY
- DEVELOP CENTER OI
  - TECHNICAL REVIEW
- IMPROVE RADC IMAGE AS CENTER OF EXPERTISE FOR C3I SIMULATION
- CONTINUE COMMITTEE

INVESTMENT STRATEGY

MODELING AND SIMULATION

- IN HOUSE MANPOWER REALLOCATION REQUIRED TO FULLY EXPLOIT CAPABILITIES AND ORCHESTRATE DEVELOPMENT OF C3I MODULAR SIMULATION PROCESS

- DEVELOP A WELL DEFINED TOP DOWN MODULAR C3I ANALYSIS STRUCTURE
  - COMMON AND VALIDATE THREAT MODELS
  - NETWORK STRUCTURES
  - DATA BASES
  - TECHNOLOGIES

- INTEGRATE SIMULATION STRUCTURE THROUGH SDDE
  - SHARE RESOURCES AND RESULTS

<u>INVESTMENT STRATEGY</u> (CONT'D)

MODELING AND SIMULATION

- NEED TO DEVELOP MEANINGFUL MEASURES OF EFFECTIVENESS
  - MULTI LEVELS/TECHNOLOGIES
- DEVELOP FULL SPECTRUM SIMULATION CAPABILITIES
  - WARGAMING TO SYSTEM TO VHSIC FABRICATION LEVEL
- DIRECT SIMULATION APPLICABILITY TO WIDER RANGE OF PROBLEMS

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